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Overview of Tight Gas Field Development in the Middle East and North Africa Region

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Abstract

As gas demand rises and operators turn to Unconventional gas reservoirs for new supplies, the need to optimize the capacity and recovery potential from this type of reservoir has risen. These Unconventional gas reservoirs represent a vast, long-term, global source of natural gas and have not been appraised in any systematic way. Unconventional gas resources—including tight sands constitute some of the largest components of remaining natural gas resources in the Middle East and North Africa. There is an emerging focus on tight gas reservoirs in the Middle East and North Africa to feed the growing energy needs in this region and save the oil from conventional resources for export and generation of hard currencies.

The greatest challenge for tight gas is to generate economic flow, so technical capabilities are needed for effective development and production of tight gas reserves, such as mineralology/geology, geomechanics, petrophysics, well engineering, and hydraulic fracturing.

During the last decade, 3-D seismic, horizontal drilling, and improved fracture stimulation have had significant impacts on tight gas production in many basins in the Middle East and North Africa.

In this paper we will present a documentation of all the tight gas reservoirs available in the Middle East and North Africa, the challenges of developing these difficult resources, the role of modern technologies in managing tight gas and improving recovery factors, and highlight the best strategies for field development in tight gas reservoirs to capitalize on the promising potential of these reservoirs.

The objective of this paper is to prepare data base to document all the tight gas reservoirs in the Middle East and North Africa and study the impact of technology on tight gas reservoir development in the emerging region.

Introduction

To keep step with the growth of world energy markets, international oil and gas operators have a duty to find economically and technologically viable solutions for accessing new resources. One Current Avenue and potential target of research is the development of unconventional gas reserves such as “tight gas”.

These unconventional gas reservoirs represent a vast, long-term, global source of natural gas and have not been appraised in any systematic way. Unconventional gas resources—including tight sands constitute some of the largest components of remaining natural gas resources in the Middle East and North Africa. Tight gas reservoir is a term commonly used to refer to a low permeability reservoir that produces mainly dry natural gas. Many of the low permeability reservoirs that have been developed in the past are sandstone, but significant quantities of gas are also produced from low-permeability carbonates, shales, and coalbed methane.

To optimize the development of tight gas reservoirs, a team of geoscientists and engineers must determine the optimum number and locations of wells to be drilled, as well as the drilling and completion procedures for each well. Often, more data and more engineering manpower are required to understand and develop unconventional gas reservoirs than are required for conventional reservoirs.

In this paper we present the challenges of developing these difficult resources, the role of modern technologies in managing tight gas and improving recovery factor, and document the available tight gas reservoirs in the Middle East and North Africa.

Challenges to the Development of Tight Gas

Fields characterized as tight gas have certain features that mean their commercial, economic, technical or operational aspects differ from other generic types of fields. They require a different level and pace of activity to ‘unlock’ resources, and the cost effective application of technology at scale to deliver commercial production and optimize project economics.

Here we will define the major challenges of developing this difficult resource.

1. Identifying resources

On conventional fields, reservoirs are identified by distinguishing between the porous rock that contains the hydrocarbons, and the cap rock that constitutes a permeability barrier. It is important to target the zones showing the greatest structural and sedimentary heterogeneity, where higher permeability creates the most promising pay zones. However, detecting these zones is very difficult because of the limited variation in the nature of the rock and therefore in its acoustic impedance.[1]

2. Low permeability and low porosity

Reservoir rock can be characterized using two parameters: porosity (φ), which expresses the volume of void space divided by the volume of the rock; and permeability (k), which indicates the ability of the formation to transmit fluids (liquid or gas) under the effect of a pressure gradient. Thus, φ is a good indicator of the volume of hydrocarbons potentially contained in a rock, while k provides information as to the mobility of the fluids. A rock may be characterized by good porosity, but the pores may be isolated from each other, which prevents fluid circulation (examples are pumice and partially cemented sandstone). In the case of tight gas reservoirs, the rocks have both low porosity and low permeability: even gas, with its low viscosity, cannot circulate easily. To exploit the resources from such reservoirs, more permeable zones – such as fractures or wells – must be created to allow the hydrocarbons to circulate. Both permeability and porosity are used to estimate the reserve.

3. Producing Reservoirs

Producing tight gas reservoirs is challenging operation, yet considering the large quantities available and long-term producibility of these natural resources, such unconventional gas is regarded as a significant source of energy for the future. Tight gas could help to address the predicted deficit between energy supply and demand in the next 5-20 years. due to the nature of tight gas reservoirs, gas migrates with great difficulty, making production highly complex. The low productivity typical of tight gas

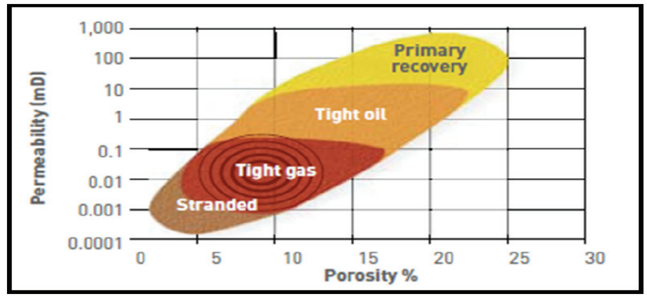

Fig. 1 The porosity and permeability of tight gas Reservoirs[1]

reservoirs is usually insufficient to ensure the economic viability of their development. The only solution is to connect as much of the reservoir volume as possible to the well.

4. Economic Estimation

Conventional techniques are not economically viable for tight gas reservoirs and only the development of new technologies can improve recovery factors by increasing reservoir porosity/relative permeability and thus the mobility of the gas.

Tight gas assets are defined as gas reservoirs having very low permeability compared to conventional gas resources. With low permeability and high geologic heterogeneity, production of tight gas assets requires high well densities and costly stimulation treatments, usually hydraulic fracturing.

Due to these and other factors, such as environmental and resource availability, tight-gas development projects yield only marginal returns at a price of $7 per thousand btu and are very sensitive to gas price fluctuations. Financial returns, therefore, depend primarily on the volume of gas an average well delivers relative to the costs of drilling and stimulation.

Tight Gas fields involve higher levels of sophisticated drilling activity which needs high cost and the need for ongoing stimulation to progressively release the gas in place; means that the investment profile for tight gas is different from conventional reservoir, also the techniques that work in one tight basin won't work elsewhere - there's always a trial and error element to find out how to do it until you figure out how to treat the reservoir the right way. So tight gas is a play requiring cost effective technology.

Largest Domestic Tight Gas Fields in Middle East and North Africa

Country	Field Name	Location of field	Geologic Age	Type of Formation	Reservoir properties		Applied Technology
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Oman	Huge khazzan and makarem gas field	Central Oman, west of the giant saih Rawl gas field	Ordovician	Sandstone	7	0.1	• Wide azimuth seismic • Directional drilling • Underbalanced drilling • Hydraulic-fracture
Saudi Arabia	Gawaher	North west	Ordovician/ Silurian	Sandstone	12	>1	• 3-D seismic • Horizontal drilling • Multi hydraulic frac stages
Saudi Arabia	Mushayab		Ordovician	Sandstone	4-6	0.001-0.008	• Horizontal drilling • Fracturing Horizontal wells • Multi hydraulic frac stages
Egypt	Obaiyed	Western desert	Middle Jurassic	Sandstone	7-13	0.1-600	• Hydraulic-fracture • Directional drilling
Egypt	Abu gharadig	Western desert	Upper cretaceous	Sandstone	8.5	.01 -200	• Directional drilling • Hydraulic-fracture
Algeria	Teguentour	South west of Algeria	Silurian – lower Devonian	Sandstone	20.1	<1	• Underbalanced drilling • Horizontal drilling • Fracturing Horizontal wells • Multi hydraulic frac stages
Algeria	Krechba	South west of Algeria	Silurian – lower Devonian	Sandstone	8.5	<1	• 2D seismic • Horizontal Drilling • Geosteering • Multi hydraulic frac stages
Algeria	In Salah	South west of Algeria	Silurian – lower Devonian	Sandstone	10		• 3D multi-azimuth seismic survey • Nuclear magnetic resonance (NMR) • Directional drilling • Hydraulic-fracture • Improved proppants
Iraq	Akkas	North west of Iraq	Upper Ordovician	Sandstone	7.6	0.13	• Wide Azimuth Seismic • Underbalanced drilling • Directional drilling • Multi hydraulic frac stages
Jordan	Risha	North east of Jordan	Upper Ordovician	Sandstone with silty clay	3-7	Less than 0.124	• Directional drilling • Hydraulic-fracture
Syria	Arak		carbonifero us	Sandstone interbedde d with shale layer	13	>1	• 2D seismic • Directional drilling • Coiled tubing drilling • Acidizing the formation matrix

Technology for Tight Gas

A concerted technology effort to better understand tight gas resource characteristics and develop solid engineering approaches is necessary for significant production increases from this low-permeability, widely dispersed resource.

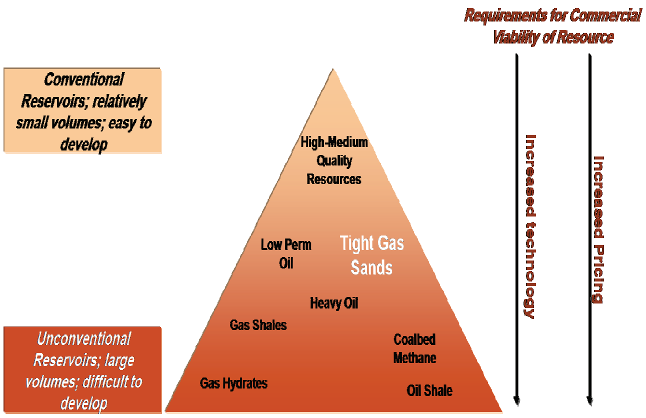

Fig. 2 Resource triangle resources vs. technology[2]

During the last decade new technologies as 3-D seismic, horizontal drilling, and improved fracture stimulation have had significant impacts on natural gas production in many tight gas reservoirs in Middle East and North Africa.

Based upon the collected information the technology used today or required to be developed to recover tight gas reservoirs was assessed for the following key areas:

1. Seismic Technology
2. Formation Evaluation Technology
3. Drilling Technology
4. Completion & Stimulation Technology
5. Other Technology Focus

1. Seismic Technology

The new seismic technologies increase the ability to accurately detect "sweet spot" areas of unconventional gas plays which are typically found by pattern drilling. By finding these sweet spots ahead of drilling, the number of poor performing, subeconomic wells would be reduced, thus improving the overall economics of the program and creating an incentive for more participation. It would also reduce the overall number of wells/drill-sites in a given geologic region, yet maintain the same overall recovery. This would create a more environmentally attractive development plan.

Seismic Methods to identify "Sweet Spots" in tight gas:

1. Time-lapse multicomponent seismic monitoring of pressure depletion in tight-gas development can be used to increase recovery efficiency.[3]
2. 3D multi-azimuth seismic survey is introducing by Total.
3. Wide azimuth seismic and leading processing techniques: it allows "See" reservoirs more clearly, choose best drilling locations , and detect fractures. BP applied it in Algeria's In Salah fields and Oman's Khazzan and Makarem fields
4. Micro-seismic fracture mapping and post fracture diagnostics: improved understanding of hydraulic fracturing in horizontal wells so that designs can be improved.
5. Cableless seismic surveying techniques: Improved density of receivers, Speed up acquisition, more sophisticated data transfer, and eliminate much of the ground disturbance associated with conventional seismic. It is useful in more remote locations where lying of cable presents its own challenges and it is introducing by BP

2. Formation Evaluation Technology

To properly complete, fracture treat, and produce a tight gas reservoir, each layer of the pay zone and the formations above and below the pay zone must be thoroughly evaluated.

The most important properties that must be known are pay zone thickness, porosity, water saturation, permeability, pressure, in-situ stress, and Young's modulus. The raw data that are used to estimate values for these important parameters come from logs, cores, well tests, drilling records, and production from offset wells.

The objectives of Formation Evaluation are to ascertain if commercially producible hydrocarbons are present, determine the best means for their recovery, to derive lithology and other information on formation characteristics for use in further exploration and development. Because tight gas reservoirs are normally also low porosity reservoirs, the importance of detailed log analyses becomes critical to understanding the reservoir. For example, if an error of 2 porosity units (p.u.) occurs when the porosity is 30%, it is normally not critical. The difference between 28 or 30% porosity will not lead to much error in net gas pay, water saturation, or gas in place. However, the same 2 p.u. error applied to a reservoir in which the porosity is 8% is a much more significant problem. The difference between 6 and 8% porosity can cause significant errors in estimates of net gas pay, water saturation, and gas in place. As such, careful preprocessing of log data and detailed petrophysical analyses of all openhole logging data are very important in the analyses of tight gas reservoirs.

The formation evaluation begins at exploration and extends to development and production optimization.

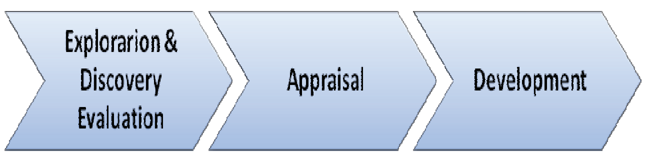

Fig. 3 Formation evaluation process

Logging Technology

- A new nuclear magnetic resonance logging technique was developed. The tool has operating and measurement advantages in tight gas sand formations over existing nuclear magnetic logging tools. The advantages are: elimination of the need to condition borehole fluids prior to logging a hole; higher sensitivity per unit sample volume; shorter instrumental dead time; and potential for greater formation penetration. The new technique has been laboratory tested in tool geometry.

- Tight reservoirs are often associated with washed-out and rugose borehole. Apparent porosity from pad type logging tools such as density, shallow resistivity and NMR is usually too high (and often useless or misleading). Even sonic tools read too high because of signal attenuation and associated waveform "stretch".[4]

- Bi-modal AcousTic Sensor provides wireline-quality compressional and shear slowness (Δt) logs in both fast and slow formations. The dual-frequency transmitters and dual seven-receiver array configuration ensure a superior signal-to-noise ratio and measurement redundancy for service reliability.
- Compensated Thermal Neutron Sensor provides accurate porosity, fluid type and lithology information for real-time decision making and wireline replacement applications.

  LWD formation tester, it is possible to obtain real-time direct pore pressure measurements, with accuracy and precision comparable to that of wireline formation testers. By using it we can Obtain real-time fluid gradients and fluid mobility (permeability/viscosity indicator), and identify fluid contact points, and de connectivity/compartmentalization, and depletion.
- Fractured and tight reservoirs require very careful petrophysical analysis in order to avoid serious overestimation of reserves

Formation Testing

The low permeability of these reservoirs slows down their response to pressure transient testing so it is difficult to obtain dynamic reservoir properties and, therefore, to characterize gas reserves.

Obtaining reliable and accurate formation pressures in microdarcy rock is a formidable challenge, but it can help determine drainage areas and appropriate well spacing for tight gas reservoirs. It is possible to measure formation pressure accurately in micro darcy rock. Dedicated tools were designed and used because conventional methods were unable to measure pressure accurately enough for well-spacing decisions. A 4D-pressure pilot was designed and installed to measure pressure drop at two observation wells equipped with pressure gauges.

3. Drilling Technology

The drilling of tight gas wells borrows from the extensive suite of technologies already made available through the conventional oil and gas industry. However, there are several difficulties that have been experienced with direct application to tight gas plays.

Middle East and North Africa drillers have directed their time and talents in capturing and implementing "drilling best practices." These "best practices" have made dramatic improvements in: (1) drilling safer, (2) drilling with less damage to the reservoir and less impact on the surface environment, (3) improving rig mobilization, and (4) drilling with less rotary drill time.

Drilling applications of tight gas reservoirs:

1. Drillbits
   - A new generation of PDC cutters that have improved the rates of penetration as much as 118% above previously used bit technology.
2. Real-time sweet-spot detection while drilling
   - It allows the steering of the drill bit to most productive areas of the reservoir.
3. Directional Drilling
   - Allows the alteration of the drill bit's dip and orientation in order to maximize the production response by optimizing the ability to cross-cut pay zones and by intersecting more fracture.
   - Enables the possible use of new drilling patterns.
4. Multi-Lateral Drilling
   - Allows more than one borehole to be drilled from a single well by drilling multi-lateral wells underground from the original surface wellbore.
   - Enables the possible use of new drilling patterns.
   - Seek to optimize the non-pay zone well section cost by drilling off the main bore
5. Underbalanced Drilling
   - Mud pressure is kept lower than the formation pressure, thereby preventing invasive formation damage and the associated risk of clogging. e.g. Implemented on the Hassi Yakour tight gas field in Algeria during the second half of 2006.
6. Horizontal drilling
   - Provides a large drainage area per well; horizontal wells in Saudi Arabia become attractive because of the relatively rapid payout from initial production rates.
   - Reducing the number of wells required to drain the reservoir.
   - Allow operator to take advantage of highly heterogeneous or layered reservoirs.
   - It provides high productivity
7. Slim hole technology
   - It drives the potential for cost reductions because a slimmer hole requires smaller drill bits, narrower production tubing and less cement, which results in fewer materials being used.
8. Coiled Tubing Drilling
   - It increases rate of penetration and improve durability.
   - Fast trip times in and out of the wellbore, because there is no need to disconnect or reattach drill pipe when tripping.
   - Coiled Tubing drilling rigs are small and light
   - Leave a smaller footprint
   - It allows rapid rig moves.

4. Completion & Stimulation Technology

Completing wells consists of testing, setting and cementing of production casing, well stimulation, and installation of tubing and downhole production equipment. Unconventional wells are tested by measuring the formation pressure to determine what type of stimulation is needed. Due to the complex dynamics at play in these reservoirs, stimulation is an important part of unconventional gas production.

Stimulation applications for tight gas reservoirs:

- Hydraulic-fracture stimulation improves the productivity of a well in a tight-gas reservoir because a long conductive fracture transforms the flow path natural gas must take to enter the wellbore.
- Multi-stage fracture treatments that can increase the production
- Fracturing Horizontal wells is even more attractive than multilateral completions, especially in tight, thick formations. It increase production rate by 2–3 times rate of vertical well.
- Develop new fracturing fluid which is strong, light-weight and does not damage the reservoir as water-based (gels and slick water) and gas-based solutions (such as nitrogen and CO_2).
- Use spherical proppant that produce better porosity and permeability in the proppant pack than irregularly shaped and sized sand particles and its idea is Once proppant placed in a fracture, the idea is to have it stay there to keep a pathway open for the gas to flow toward the wellbore.
- Low pressure stimulation technique used to reduce formation pressure (by dewatering the free gas zone).
- Microseismic monitoring was used to measure the azimuth, length and height of a hydraulic fracturing and providing a survey design and fracture characterization.

Completion applications for tight gas reservoirs:

- Equipment and electronic sensors that can withstand the high temperature and pressure regimes.
- Expandable pipe for larger bottom-hole production equipment without adding number of casing strings.
- “Smart well” technologies to enable the multizone completion and controls while preventing costly future well intervention.
- Principles of Propellant/Perforating: The option that promised best results was to use the new propellant-perforating stimulation techniques. Propellant is a combination of an oxidizer and a fuel burns rapidly when ignited, generating large volumes of high-pressure combustion gases. The burning of the propellant produces a pressure load on the formation that is below the compressive yield strength of the formation rock. As the pressure increases, strain energy is accumulated in the rock matrix until the circumferential stress around the wellbore exceeds the strength of the rock and a fracture is initiated.
- Casing Conveyed Perforating System (CCPS), which has revolutionized multizone fracturing operations. The CCPS facilitates pinpoint stimulation of multiple pay intervals in a relatively short time and improves stimulation quality, hydrocarbon recovery and well economics.
- New systems not only for propellant assisted perforating improve penetration into the tight formation, but it also cleans up after itself, in effect stimulating the near-wellbore area. This reduces the horsepower required for subsequent fracturing operations.

5. Other Technology focus

- Petrophysics is a critical technology required for understanding low-permeability reservoirs.
- Geomechanics and subsurface understanding is a critical component in understanding the nature of the formation All companies recognise the need to use geomechanics to assess natural fracture patterns
    - Permeability – magnitude and direction
    - Distribution of natural fractures
    - Change of permeability with depletion

Conclusion

We conclude that approaching tight gas will require paradigm shift of what we are doing today at the Middle East and North Africa. It requires an integral approach of all the technology available as highlighted in this paper to unlock this big resource for the future of the region and saving oil for exporting, petrochemical industry, and generation of hard currency.

References

1. Total, 2006 "Tight Gas Reservoirs", 2006

2. Stephen A. Holditch, SPE, Texas A&M U , "Tight Gas Sands", paper 103356-MS, June 2006

3. Thomas L. Davis and Robert D. Benson, "Tight-gas seismic monitoring, Rulison Field, Colorado", April 2009.

4. M.M. Abu-Shanab, BAPETCO, E&P, EGPC/Shell J.V., Egypt, G.M. Hamada, A.A. Abdel Wally, Faculty of Engineering, Cairo University, Egypt, M.El. Oraby, Halliburton energy Service, Egypt, " IMPROVED POROSITY ESTIMATION IN TIGHT GAS RESERVOIRS FROM NMR AND DENSITY LOGS", paper SCA2005-57 presented at the International Symposium of the Society of Core Analysts, Toronto, Canada, 21-25 August 2005

5. The National Petroleum Council (NPC), 2007 "UNCONVENTIONAL GAS", 18 july, 2007

6. James R. Ammer, Gary L. Covatch, Gary P. Sames, Thomas H. Mroz, William J. Gwilliam, U.S. Department of Energy, National Energy Technology Laboratory "Technology for Increased Production from Low-Permeability Gas Reservoirs: An Overview of U.S. DOE's Gas Program - Successes and Future Plans" paper 60310-MS SPE Rocky Mountain Regional/Low-Permeability Reservoirs Symposium and Exhibition, 12-15 March 2000, Denver, Colorado

7. PTAC, 2006 "Unconventional Gas Technology Roadmap", June, 2006

8. G.C.Naik, "Tight Gas Reservoirs – An Unconventional Natural Energy Source for the Future"

9. Dutton S., Clift S., Hamilton D., et. al., 1993, Major Low Permeability Sandstone Gas Reservoirs in the Continental United States, Bureau of Economic Geology, University of Texas, Austin.

10. Gray, J. 2005. “New stimulation techniques for unconventional gas”, 7th Annual Unconventional Gas Conference, Canadian Society for Unconventional Gas, November 8-10, 2005.